A Low-Cost Airborne EO Oceanographic Measurement System

J. Zandy Williams
Arete Associates
1725 Jefferson Davis HWY
Suite 703
Arlington, VA 22202
phone: (703) 413-0290 fax: (703) 413-0295 e-mail: williams@arete-dc.com

Contract Number: N00014-02-C-0183
http://www.aross.arete-dc.com

LONG-TERM GOALS

With the emphasis of the ONR Coastal Dynamics Programs on model-driven experiments, there is a need for reliable measurements to develop, drive and validate shoaling wave models. Measurements by research vessels and *in situ* instruments provide data at discrete points while measurements by satellite sensors provide only snapshots of a large area. This project seeks to develop a system capable of addressing the need for medium-area, time-series measurements for the advancement of shoaling-wave models.

OBJECTIVES

This effort will development a passive, electro-optical imaging system that can be mounted and flown in an aerial photography airplane to produce time-series imagery of the ocean surface suitable for scientific research. The system is designed for low-cost production through the use of commercial-off-the (COTS) components and low-cost operation through the use of commercial airplanes.

APPROACH

The system design is based on technology developed for the Airborne Remote Optical Spotlight Sensor (AROSS) and will be adapted to accommodate the necessary modifications for use on commercially available aerial platforms. AROSS was developed as a research and development (R&D) system that acts as a surrogate for future UAV payloads that would be used in combat, under contested conditions. The AROSS design approach was to utilize a turret-type positioner, digital framing camera, and integrated Global Positioning System/inertial measurement unit (GPS/IMU), with a computer-based data acquisition and control system. Attitude and position information is provided by the GPS/IMU, which was mounted within the turret rather than on the airframe. The control system uses this information, along with differential GPS corrections, to calculate the camera pointing direction and maintain the intended geodetic location of the aim point in close proximity to the center of the image while maintaining a standoff range suitable for military applications.

Although AROSS is a demonstrated success, its routine use is limited by its significant cost to operate. While not expensive by military standards, the approximate cost of $2000 per hour to fly the specialized UAV surrogate in which AROSS is mounted restricts its non-warfare or commercial use and its participation in ongoing scientific research.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2003**	2. REPORT TYPE	3. DATES COVERED **00-00-2003 to 00-00-2003**

4. TITLE AND SUBTITLE **A Low-Cost Airborne EO Oceanographic Measurement System**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Arete Associates,1725 Jefferson Davis HWY,,Suite 703,,Arlington,,VA,22202**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

The new system will reduce operating costs by using commercial, aerial-photography airplanes. It is designed to replace the large-format camera and will extend into the camera viewport, which is located in the floor of the airplane. This configuration will place the sensor near the skin of the fuselage and will allow the system to stare at a geodetic location at oblique angles. In addition to the needed modifications for use on commercial airplanes, the development of a next generation AROSS also represents an opportunity to develop a multi-channel sensor to replace the panchromatic camera in AROSS. The new system will be called AROSS-Multi-Channel or AROSS-MC.

Figure 1: Completed hardware for the AROSS-MC positioner and payload

WORK COMPLETED

During the past year, hardware was acquired and integrated into the final system. Several modifications and refinements were made to the design to accommodate unforeseen issues with integration. Software development occurred concurrently with the hardware development. The hardware integration has been completed and the control software is nearing completion. As part of the integration, land tests of the system were conducted during the summer of 2003. These tests simulated airplane flight and were used to finalize and refine the system design. Following the land test, the first flight test of AROSS-MC was performed in September 2003.

RESULTS

The AROSS-MC hardware integration has been completed and successfully tested. A photograph of the system is shown in Figure 1. As a result of the land tests, the control and pointing algorithm portion of the control software was also completed.

Figure 2. Mapped or geo-rectified AROSS-MC Image from the test flight on Sep 11, 2003 over the Martisnburg, WV airport
[geo-rectified image of runway and hangars]

Data from the first flight test has been examined to investigate the ability to geo-rectify or ground-map the imagery from AROSS-MC. Using information from the GPS/INS, an image from the red camera has been mapped and is shown in Figure 2.

In addition to obtaining time-series imagery, data from the first flight test was examined to determine the ability to co-align to the different cameras in AROSS-MC. Figure 3 shows images from the red (600 nm – 700 nm) and blue (500 nm – 600 nm) cameras. Note that the detail in the red camera is better resolved than in the blue camera. This is an expected result and is caused by the increased scattering of light at blue wavelengths versus red wavelengths. Figure 4 shows a difference of the two channels. The absence of "ghosts" in this image indicates that the two channels are well aligned and the residual vales are the result of the differences in the emitting passbands of the objects in the scene.

IMPACT/APPLICATIONS

The successful transfer of AROSS technology to a system capable of being mounted in a commercial aircraft will provide an inexpensive oceanographic research asset. This asset will directly benefit the Navy wave modeling community who require wide-area measurements of observable parameters, including bathymetry, currents, and directional wave spectra, in the littoral zone. The lower operating cost of AROSS-MC will be more in-line with the budgets of typical field experiments designed to enhance scientific understanding of coastal processes. Government agencies responsible for coastal waterways, such as the Army Corps of Engineers, and mapping, such as NOAA and NIMA, represent potential customers who can utilize the low-cost rapid bathymetric and current survey capability of the new system.

Figure 3. AROSS-MC Imagery from the test flight on Sep 11, 2003 over the Martisnburg, WV airport, the left frame is the red channel and the right frame is the blue channel. [images of runway and hangars, left image has greater resolution than right image]

TRANSITIONS

None

RELATED PROJECTS

The Airborne Optical Spotlight System (AROSS) is a compact, turret-based optical system designed and constructed for passive imaging of ocean waves using a small aircraft. The purpose of the system is to collect time series of images that are mapped to a common geodetic surface in order to extract the space-time characteristics of the waves. This is achieved by staring at a fixed geodetic location, and accurately measuring the imaging geometry. The system was designed to be compact and lightweight for future installation on an unmanned aerial vehicle (UAV), and has been installed on a specially modified, small, manned, single-engine aircraft for testing and experimentation. Tests have confirmed

successful operation of the staring capability at moderate distances to a fixed target array on land and to the nearshore region with shoaling gravity waves. These capabilities are the result of a successful previous ONR-funded SBIR. More information can be found at http://www.aross.arete-dc.com.

Figure 4. Difference of red and blue channel of a frame of AROSS-MC Imagery from the test flight on Sep 11, 2003 over the Martisnburg, WV airport [images of runway and hangars]

REFERENCES

Dugan, J.P., Piotrowski, C.C., Williams, J.Z., "Water depth and current retrievals from airborne optical measurements of surface gravity wave dispersion," *J. Geophys. Res*., 106 (C8), 2001, 16903-16915

Dugan, J.P., G.J. Fetzer, J. Bowden, G.J. Farruggia, J.Z. Williams, C.C. Piotrowski, K. Vierra, D. Campion and D.N. Sitter, "Airborne optical spotlight system for remote sensing of ocean waves", *J. Atmos. and Oceanic Technol*., 18 (7), 2001, 1267-1276

Dugan, J.P. and C.C. Piotrowski, Surface current measurements using visible image time series, *Remote Sensing of Environment*, Nov 2002 (in press).

Piotrowski, C.C., J.P. Dugan and J.Z. Williams, Accuracy of bathymetry and current retrievals from airborne optical time series imaging of shoaling waves, *IEEE Trans. Geoscience and Remote Sensing*, Nov 2002 (in press).